Estimate of the energy spread from the longitudinal resistive wall wakefield in LUX

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The longitudinal wakefield from the wall resistance of a circular pipe of radius b, length L, electrical conductivity σ_c, at distance z behind the exciting charge, is given by [Chao]:

$$W' = \frac{cL}{2\pi b z^{3/2}} \sqrt{\frac{Z_0}{\pi \sigma_c}}$$

The rms relative energy spread for a Gaussian bunch distribution of length σ_z is given by [LCLS], [Napo]:

$$\sigma_{\Gamma RW} = 0.22 \frac{ecNL}{\pi^2 b \frac{E}{e} \sigma_z^{3/2}} \sqrt{\frac{Z_0}{\pi \sigma_c}}$$

provided that the bunch length is significantly longer than the characteristic length s_0

$$s_0 = \left(\frac{2b^2}{Z_0 \pi \sigma_c} \right)^{1/3}$$

For LUX parameters with chamber radius ~ 3.5 mm, and conductivity $\sigma_c = 3.5 \times 10^7$ (Al), this condition is satisfied; $s_0 \approx 10^{-5}$, much less than the bunch length of ~ 10^{-4} m. Table 1 shows the rms energy spread for two cases of rms bunch lengths 0.4 mm (FWHM 3 ps) and 0.25 mm (FWHM 2 ps), for each pass, number of electrons N = 6.24×10^9 (1nC). The total energy spread from the longitudinal resistive wall wakefield is then 1.6×10^{-4} for a 3 ps bunch duration, and 3.2×10^{-4} for a 2 ps bunch duration. Table 2 shows estimates for the insertion devices.

Table 1. Energy spread for each arc

Beam energy (GeV)	ρ (dipole length) (aperture 7 mm) (m)	λ (arc length) (aperture 30 mm) (m)	Energy spread $\sigma_{\Gamma RW}$	
			σ_z = 0.4 mm	σ_z = 0.25 mm
0.1	2.5	12	4.15E-05	8.40E-05
0.85	14.4	122	3.95E-05	7.99E-05
1.6	28.8	126	2.85E-05	5.77E-05
2.35	43.2	143	2.55E-05	5.17E-05
3.1	48	152	2.11E-05	4.27E-05

Table 2. Energy spread for insertion devices

Beam energy (GeV)	□ (insertion device) (aperture 4 mm) (m)	Energy spread □□RW	
		□z = 0.4 mm	□z = 0.25 mm
For the hard X-ray insertion devices			
3.1	16.1	7.12E-06	1.44E-05
For the FEL chains			
2.35	50	2.92E-05	5.90E-05
3.1	50	2.21E-05	4.47E-05

Figure 1 shows the longitudinal bunch profile (blue) and resistive wall wakefield (red) for a rectangular bunch of 2 ps full width, in a 1 m vacuum chamber of radius 3.5 mm. The maximum longitudinal kick is 19 V/pC, and the rms value within the bunch is 15.8 V/pC, resulting in an rms energy deviation of 5×10^{-6} (per meter) for a 1 nC bunch at 3.1 GeV, slightly greater than the estimates above.

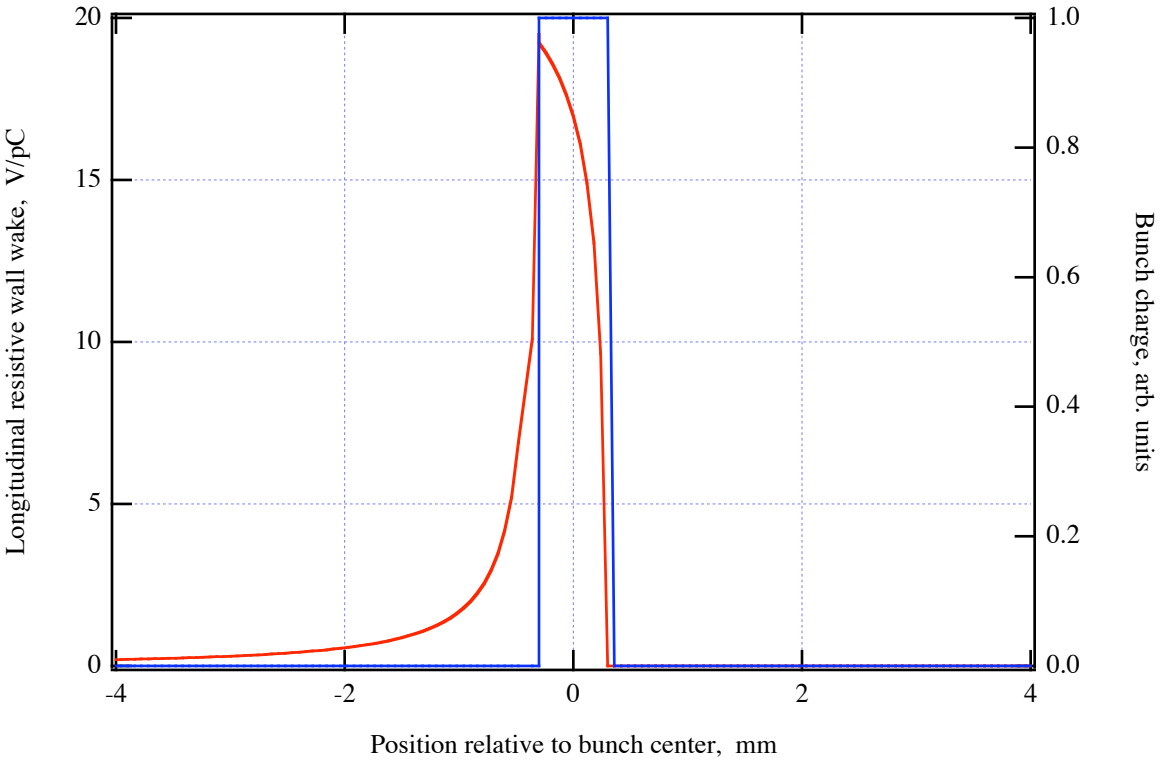

Figure 1. Longitudinal resistive wall wakefield (red) for a rectangular bunch of 2 ps duration (blue).

Conclusion

The energy spread arising from the resistive wall wakefield appears to be a small effect in LUX.

References

[Chao] A. Chao, M. Tigner eds, Handbook of Accelerator Physics and Engineering, World Scientific, 1999, ISBN 9810235003, p. 204.

[Napo] O. Napoly and O. Henry, "The resistive-pipe wake potentials for short bunches", Particle Accelerators, Vol. 35, pp. 235-247, 1991.

[LCLS] LCLS Design Study Report, SLAC-R-521, 1998, p. 7-55.